2019-07

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10.1016/j.healthplace.2019.102160
Health and Place
Elsevier

This is the Author's copy of a paper to appear as: Martin, L., Pahl, S., White, M. P., & May, J. (2019). Natural environments and craving: The mediating role of negative affect. *Health & place, 58,* 102160.

Natural Environments and Craving: the Mediating Role of Negative Affect.

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Conflicts of interest: none.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Abstract

This paper presents a novel investigation of a conceptual model, proposing that increased nature exposure may be associated with lower cravings, through reductions in negative affect. A cross-sectional online survey (N=149) provided an initial exploration of the relationships between various aspects of nature exposure, craving and negative affect. Access to gardens/allotments and residential views incorporating more than 25% greenspace were both associated with reductions in the strength and frequency of cravings. These associations were mediated, to varying degrees, by reductions in negative affect. This novel link could have implications for public health and environmental protection programmes.

Highlights:

- A conceptual model of the relations between nature, craving and affect is proposed.
- A cross sectional survey provided an initial exploration of this model.
- Green views were inversely associated with craving strength and frequency.
- Access to a garden/allotment was inversely associated with craving.
- These associations were mediated by reduced negative affect.

Keywords: Natural Environments, Greenspace, Craving, Affect, Mood

1. Introduction

1.1 Craving

Smoking, drinking excessive amounts of alcohol, unhealthy eating and illicit drug use pose some of the greatest challenges to public health (Beaglehole et al., 2011; Strum, 2002). In many cases an immediate precursor of these behaviours is an emotionally charged mental state characterised by an intense desire to engage in the behaviour, frequently referred to as a *craving* (May, Kavanagh & Andrade, 2015). As well as predicting consumption patterns across a range of unhealthy behaviours (*Smoking*, Cosci, Bertoli, Pistelli & Carrozzi, 2016; *Snacking*, Richard, Meule, Reichenberger & Blechert, 2017; Hamilton et al., 2013; *Binge-drinking*, Rosenberg & Mazzola, 2007), craving also predicts relapse rates for abstinent smokers (Berlin, Singleton & Heishman, 2013), alcohol-dependent individuals (Bottlender & Soyka, 2004), and dieters (Sitton, 1991). Both the strength and frequency of cravings are predicted by negative affective states such as stress, anxiety and depression (Kavanagh, May & Andrade, 2009; McCaul, Hutton, Stephens, Xu & Wand, 2017). In other words, people are most likely to experience more frequent and intense cravings, and act on these cravings, when they are in negative affective states.

Consequently, there have been various attempts to reduce cravings and their associated negative consumption behaviours though reducing negative affect, notably through encouraging bouts of light-moderate physical activity (Haasova et al. 2013; Taylor et al., 2007; Ussher, Taylor & Faulkner, 2012). There is good evidence that physical activity in and of itself can improve mood (Fox, 1999). However, much of the previous research into physical activity and craving in particular involved physical activity, such as walking and cycling outside and in quasi-natural

environments such as parks (Haasova et al., 2013). This is potentially important because there is also evidence that physical activity undertaken in natural settings is associated with weaker negative emotions than activity conducted indoors or in built-up and urban settings (Thompson Coon et al., 2011). In other words, it is unclear if reductions in cravings in earlier studies was due to the physical activity itself or to the environment where it took place.

1.2 Natural environments and mood

There is now a considerable body of evidence showing that even short (e.g. 10-15 minute) exposures to natural environments are associated with a reduction in negative (e.g. anxiety) affective states (Bowler et al., 2010; McMahan & Estes, 2015). Moreover, the more frequently an individual makes recreational visits to natural environments, the lower their odds of exhibiting mild-to-moderate depression (Cox et al., 2017), and the greater their odds of reporting high levels of eudaimonic well-being (i.e. the feeling that one's life is worthwhile; White, Pahl, Wheeler, Depledge & Fleming, 2017).

Chronic exposure to natural environments, in the form of higher levels of neighbourhood greenspace, is also associated with reduced stress (Ward-Thompson, Aspinall, Roe, Robertson & Miller, 2016), depression and negative affect (Beyer et al., 2014; Cox et al. 2017), even among identical twins (Cohen-Cline, Turkheimer & Duncan, 2015). Similar affective benefits are observed for green residential views and access to gardens/allotments (Kaplan 2001; Ward-Thompson et al., 2016). In short, given the relationship between affect and craving, it seems plausible to hypothesise that individuals with greater exposure to natural environments will also have lower frequency and intensity of cravings because they

have generally lower levels of negative affect. Two further strands of evidence support this possibility.

1.3 Natural environments and craving

First, at least two nature-based treatment programmes have shown attenuated cravings amongst individuals undergoing drug and alcohol rehabilitation. Bennett, Cardone and Jarczyk (1998) compared the efficacy of a three-day wilderness experience and treatment-as-usual within a residential setting. They found that post-intervention craving scores were lower in participants assigned to the intervention, relative to those who received residential treatment. Further, in a qualitative study, White et al. (2016) reported improvements in affect and reductions in craving in individuals undergoing drug and alcohol rehabilitation, following a week-long sail training voyage.

The second strand of evidence is incidental. Specifically, we know of several studies which have used an imagery based task to help reduce craving, where the imagery involved a natural setting (e.g. *beach,* Versland & Rosenberg, 2007; *woodland*, Hamilton, Fawson, May, Andrade & Kavanagh, 2013). Thus, similar to the physical activity studies reviewed above, it remains possible that it was imagery of nature, rather than images *per se*, that were responsible for the reduction in cravings.

1.4 The current research

Given the potential for natural environments to offer a cost-effective and unobtrusive means of reducing craving, it is important to establish not only the mechanisms which may underlie this relationship, but also which particular components of nature exposure are the most likely candidates for reducing craving.

The current study aimed to investigate these two underexplored issues, using a cross-sectional approach to explore our conceptual model. Specifically, an online survey across Southern England was utilised to provide an initial test of the associations between various types of nature exposure, craving and negative affect. Briefly, the strength and frequency of cravings were assessed using the Craving Experiences Questionnaire (May et al., 2014), and the Depression, Anxiety and Stress Scale (Lovibond & Lovibond, 1995) constituted a measure of negative affect. Consistent with prior research, local nature exposure was operationalised in terms of: 1) the proportion of greenspace in an individual's residential neighbourhood; the presence of green views from their home; their access to a garden/allotment; and 4) their frequency of use of public greenspaces.

The study addressed two principal research questions: 1) Is greater exposure to natural environments associated with reduced craving? and 2) Is any such relationship mediated by negative affect? In addition, the relative contributions of different types of nature exposure on craving and affect were investigated. Hypothesised relationships are depicted in Figure 1. Based on prior research on the general benefits of nature, inverse relationships were predicted between exposure to natural environments and both the strength and frequency of craving. Additionally, it was hypothesised that these relationships would be mediated by reductions in negative affect. In line with prior research on the broader psychological benefits of nature (White et al., 2013), the contributions of different types of nature exposures were expected to be cumulative.

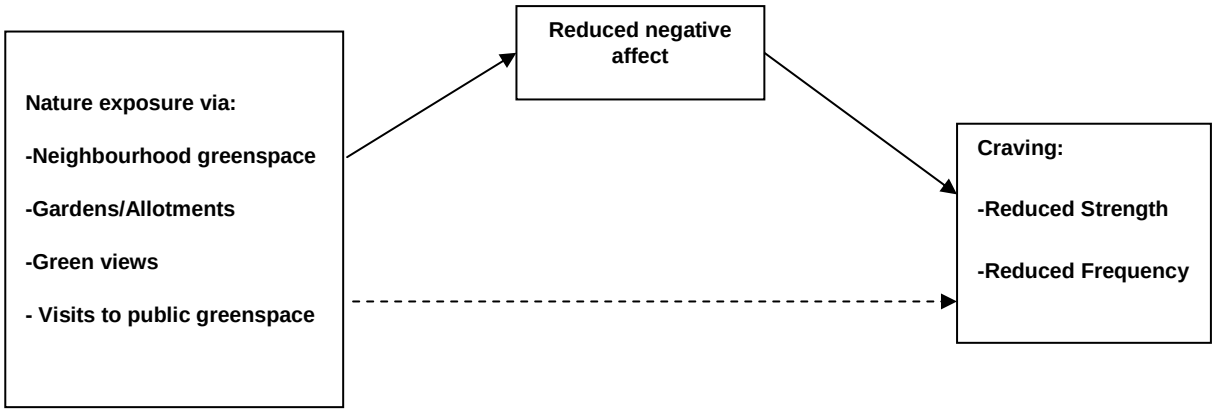

Figure 1: Conceptual model depicting hypothesised relationships between natural environments, negative affect and craving outcomes. Solid lines represent direct relationships, dotted lines depict indirect relationships.

2. Method

2.1 Participants

A cross-sectional online survey was designed and sent to two occupational cohorts: 1) Employees of Health Education England and NHS partnership organisations across Southern England and 2) Employees at the University of Plymouth. The final sample comprised of a total 149 participants (112 females) aged between 21 and 65 years (median age = 41 years).

2.2 Measures

The face validity of the survey was examined through a small-scale pilot study administered to an opportunity sample (N = 6) to ensure that the final version was relevant, concise, and as clear as possible. The finalised survey took approximately 15 minutes to complete and comprised of a series of standardised measures presented to participants in four sections: demographics, affect, craving and aspects

of the local environment. Demographic information, including partial-postcode, was obtained first, with the remaining sections counterbalanced between participants to alleviate any order effects.

2.2.1 Craving

Participants selected an appetitive target for which they regularly experienced cravings: food (38%), chocolate (32%), caffeine based substances (16%), nicotine (5%), alcohol (9%), other (1%). Following Skorka-Brown, Andrade, Whalley and May (2015), substances were divided into those that were potentially addictive (alcohol, nicotine, caffeine) *vs*. non-additive substances (food, chocolate, other) and we refer to this as 'craving target' throughout. Craving target was included as a dichotomised variable within multivariate analyses due to its potential to confound craving and socio-economic measures. Notably, use of addictive substances (e.g. tobacco) tends to be higher amongst individuals in lower socio-economic groups (Stringhini et al., 2017) and is positively associated with neighbourhood deprivation (Lyratzopoulos, Heller, McElduff, Hanily & Lewis, 2006). Self-reported cravings for the selected appetitive target over the past week were assessed using the *Strength* and *Frequency* forms of the Craving Experience Questionnaire (CEQ-S and CEQ-F respectively; May et al., 2014). With a robust factor structure across craving targets and high degree of convergent validity with associated measures, both forms of the CEQ have been widely used within prior research (Kavanagh et al., 2009). Each subset of the CEQ contains a total of 11 questions scored on an 11-point Likert scale pertaining to three factors: intensity (e.g. How much/often did you want it?), imagery (e.g. How much/often did you imagine the sensory aspects of consumption?) and intrusiveness (e.g. strength/frequency of intrusive thoughts). Item scores

corresponding to the two forms were totalled and divided by eleven, resulting in mean scores of 0-11 for the CEQ-S and CEQ-F, with higher scores indicating increased strength and frequency of craving, respectively. Mean craving strength and frequency in the present study were 4.67 (SD = 2.16) and 3.81 (SD= 2.23), respectively. Each scale demonstrated excellent internal consistency (CEQ-S α = .91, CEQ-F α = .93).

2.2.2 Nature Exposure

Following previous survey studies (e.g. Weinstein et al., 2015), we used a range of neighbourhood and self-reported nature exposure metrics.

*Neighbourhood greenspace***:** Percentage neighbourhood greenspace was determined by mapping participants' postcodes to an established Lower-layer Super Output Area (LSOAs) dataset, which has been used in prior research (White et al., 2017). Derived from the Generalised Land Use Database (Department for Communities and Local Government, 2007), the dataset provides a proportional measure of land cover, incorporating public greenspace and domestic gardens within each LSOA. As the data was only available for 143 participants, analyses including this variable exclude six participants. The mean proportion of neighbourhood greenspace within the current study was 65.49% (SD = 20.90). Scores on the item were dichotomised around the median, with scores above 64.20 reflecting high neighbourhood greenspace (*vs.* low = reference).

*View from the home***:** prior operationalisations of view from the home as the presence/absence of green views (Ward-Thompson et al., 2016; Kaplan, 2001) do

not account for variations in the proportion of greenspace between participants' views from the home. Consequently, within the present study participants were required to estimate the proportion of the view from their home comprising of greenspace. Given large skews in the distribution, green view was dichotomised around the median, with a proportion of greenspace within the view from home exceeding 25% classified as high (*vs*. low = reference).

*Garden/Allotment***:** consistent with previous research (Ward-Thompson et al., 2016) this variable was operationalised as whether participants had access to a private garden/allotment (Yes *vs*. No = reference).

*Greenspace use***:** frequency of use of public natural spaces for recreation distinguished between the following location types: Green urban (e.g. a park within a town or city), Green rural (e.g. farm land). Participants were required to indicate frequency of use of each environment type over the last twelve months, using standardised response options employed in prior research (More than once per day, Every day, Several times a week, Once a week, Once or twice a month, Once every 2-3 months, Once or twice, Never; Natural England, 2015). With no significant differences in the frequency of use of urban or rural indicators, $t(148) = 0.15$, $p = .44$ the data was collapsed between variables to produce a composite measure of public greenspace use. The indicator was dichotomised as frequent use (≥ once a week) *vs.* infrequent use (< once a week = reference) to ensure a consistent temporal frame with craving and affect measures.

2.2.3 Negative Affect

With favourable psychometric properties and high levels of reliability in non-clinical samples, the short form of the Depression, Anxiety and Stress Scale (DASS-21, Lovibond & Lovibond, 1995; Crawford & Henry, 2003) was used to measure negative affect. The measure consists of 21 items describing possible affective states, corresponding to the three subscales of depression, anxiety and stress. Participants were required to indicate on a 4-point Likert scale the extent to which each statement applied to them within the last week (0, 'Did not apply to me at all' - 3, 'Applied to me very much, or most of the time'). Item scores corresponding to the three subscales were totalled and multiplied by two, to yield total scores of 0-42 for depression, anxiety and stress, with higher scores on each subscale indicating increased symptomology. Subscales showed good internal reliability (depression $\alpha = .92$, anxiety $\alpha = .84$, stress $\alpha = .83$) and typical inter-correlations for this measure (depression-anxiety, $r = .72$; depression-stress $r = .67$; anxiety-stress $r = .68$; $p < .001$ in each case). Following Lovibond and Lovibond (1995), the mean of the three subscale scores was used to produce a composite measure of negative affect ($M= 26.20$, $SD= 20.73$, $\alpha = .94$). The composite measure exhibited a moderate positive skew, which was correctable by square-root transformation (skewness, 0.01; kurtosis, 0.36). However, as sensitivity analyses revealed consistent findings between multivariate models using the transformed and untransformed variable, those based on the untransformed data are reported here for interpretability.

2.2.4 Individual-level control variables

Demographic characteristics, as well as potential covariates identified within previous research (Van Herzele & de Vries, 2012; Triguero-Mas et al., 2015; Ward-

Thompson et al., 2016) were obtained. Demographic variables included: age and sex. There is evidence that access to natural spaces has a socio-economic gradient, with better access among more educated and wealthier groups (Boone, Buckley, Grove, & Sister, 2009; Iverson and Cook, 2000; Shanahan et al., 2014). Consequently, academic attainment (secondary/college (ref); undergraduate; postgraduate) was included in our models to at least partially account for this bias. Other individual level control variables were single item measures of: neighbourhood satisfaction ('I live in a nice neighbourhood', 1- totally disagree, 7- totally agree); satisfaction with social support ('How satisfied are you with the support you get from your friends?' , 1 - very dissatisfied, 7- very satisfied) and place belonging ('how strongly do you feel you belong to your neighbourhood or local area?', 1- not at all, 7- very much so). Given large skews in the distribution of all three items, scores were dichotomised around the median. Specifically, scores of 6–7 on the first two items reflected high (*vs*. low = reference) scores (and included 59% and 58% of the sample respectively) and scores of 4-7 on the final item reflected high (*vs*. low = reference) place belonging, including 68% of the sample. Additionally, a single-item instrument developed by Milton, Bull and Bauman (2010) provided a measure of physical activity level. The item required participants to indicate, within the last week, how many days they engaged in a total of 30 minutes or more of physical activity that was enough to raise their breathing rate (0-7). Scores on the item were dichotomised according to whether participants met the UK guidelines (Bull and the Expert Working Group, 2010) of engaging 30 minutes of moderate-intensity activity at least 5 times per week (Yes *vs*. No = reference; including 30% and 70% of the sample, respectively).

3. Results

3.1. Statistical Approach

Analyses were conducted using STATA 14 (StataCorp, College Station, TX). T-tests were conducted to examine the bivariate effects of each environmental indicator (neighborhood greenspace, view, garden, visit frequency) on the two main outcome variables (craving strength and frequency) predicted mediator (negative affect).

A series of multiple regression models were then fitted to examine the relative contribution of environmental indicators to each outcome measure, as well as the hypothesised mediating role of negative affect. Regression analyses presented here were adjusted for potential individual-level confounders identified from prior research. Unadjusted models are reported in Supplementary Materials 1 for information. Further models adjusted for our area-level confounders (i.e. neighbourhood deprivation and degree of urbanicity) are also provided in Supplementary Materials 2. The direction and strength of the associations between variables were largely consistent with those observed in final models.

Following Baron and Kenny (1986), a series of regression models were fitted estimating: a) craving measures; and b) negative affect, with environmental indicators entered as predictors; and c) craving measures with environmental indicators and negative affect simultaneously entered into the same model. Where including negative affect in the model reduced the associations between environmental predictors and craving measures, mediation effects were formally tested using Structural Equation Modelling (SEM). Allowing for the estimation of all indirect and direct effects within a single model, SEM has several advantages over traditional tests of mediation (MacKinnon, 2008). Specifically, multiple mediation

models are able to show the unique mediating effects controlling for the presence of other variables, whilst reducing the likelihood of parameter bias associated with omitted variables (Preacher & Hayes, 2008). Models exploring the possibility of alternative mediating directions were also tested using SEM. As recommended for small samples (Preacher & Hayes, 2004) all models tested here used maximum likelihood estimation with a bootstrap resample of 1000.

3.2. Preliminary Results: High vs. Low Greenspace Exposure

Descriptive statistics and bivariate analyses for all outcome measures as a function of environmental indicators are presented in Table 1. About half of the respondents (55%) reported 'high' greenspace views from the home (>25% of greenspace, see categorisation above), 75% reported having access to a garden/allotment, and about half of the sample (60%) reported frequent greenspace use (≥ once a week, see categorisation above).

Whilst respondents residing in high greenspace neighbourhoods reported lower craving strength, $t(141) = 2.17$, $p < .02$ and negative affect, $t(141) = 2.53$, $p = .01$, compared to those living in low greenspace neighbourhoods, there were no significant differences in craving frequency, $t(147) = 1.67$, $p = .10$. Participants with high greenspace views from their home exhibited significantly lower craving strength, $t(147) = 4.00$, $p = .0001$, craving frequency, $t(147) = 3.91$, $p = .0001$, and negative affect, $t(147) = 4.40$, $p < .0001$ relative to those with low greenspace views. Similarly,

Table 1: Summary of means (standard deviations) and bivariate tests for outcome variables as a function of environmental indicator.

	N (%)	Craving Strength	Craving Frequency	Negative Affect
Neighbourhood greenspace				
Low	70 (49%)	5.09 (2.12)*	4.14 (2.33)	10.30 (7.71)**
High	73 (51%)	4.31 (2.17)	3.51 (2.15)	7.40 (5.89)
Greenspace in view				
Low	67 (45%)	5.42 (1.90)***	4.57 (2.26)***	11.33 (7.93)***
High	82 (55%)	4.06 (2.17)	3.20 (22.19)	6.61 (5.09)
Access to Garden/Allotment				
No	37 (25%)	5.78 (2.14)***	5.19 (2.48)***	13.05 (8.82)***
Yes	112 (75%)	4.30 (2.05)	3.36 (2.22)	7.31 (5.50)
Public greenspace use				
< Weekly	60 (40%)	4.98 (2.35)	4.04 (2.55)	10.98 (8.24)***
≥ Once a week	89 (60%)	4.46 (2.01)	3.66 (1.98)	7.22 (5.39)

Note: *p <.05; **p <.01; ***p<.001.

participants with access to a garden/allotment reported significantly lower strength, $t(147) = 3.76$, $p = .0002$, and frequency of cravings, $t(147) = 4.63$, $p = .0000$, as well as reduced negative affect, $t(147) = 4.68$, $p < .0001$ compared to those with no access to such resources. Neither the strength or frequency of craving differed as a function of the frequency of public greenspace use, $t(147) = 1.42$, $p = .16$ and $t(147) = 1.01$, $p = .31$, respectively. Conversely, individuals visiting public greenspaces atleast once a week reported lower negative affect, $t(147) = 3.37$, $p = .001$, relative to those who visited greenspaces less frequently. Overall, this is consistent with the hypothesised association between increased nature exposure and positive outcomes, but this needs to be tested also while controlling for relevant covariates.

3.3. Main Findings

Adjusted regression models of nature exposure and the three outcome measures, controlling for individual-level covariates, are reported in Table 2.

Table 2: Adjusted regression models predicting craving strength, craving frequency and negative affect from environmental indicators.

	Model 1 Craving Strength		Model 2 Craving Frequency		Model 3 Negative Affect (NA)		Model 4 Craving Strength & NA		Model 5 Craving Frequency & NA	
	β	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**
Local greenspace										
High neighbourhood greenspace	-.02	.39	.03	.39	-.01	1.09	-.012	.36	.04	.36
High greenspace view from home	-.24*	.41	-.23*	.41	-.25**	1.14	-.14	.39	-.13	.40
Access to garden/allotment (Yes)	-.24*	.48	-.26**	.48	-.20*	1.34	-.15	.46	-.17	.46
Greenspace visits (≥ Once a week)	-.06	.36	-.05	.37	-.21**	1.01	.02	.35	.04	.35
Area perceptions										
High neighbourhood satisfaction	.09	.42	.02	.43	-.01	1.19	.09	.40	.02	.40
High place belonging	.01	.45	.01	.46	.06	1.27	-.02	.42	-.02	.43
Socio-demographics										
Age	-.12	.02	-.18*	.02	-.15	.05	-.06	.02	-.11	.02
Female	.12	.42	.09	.41	.12	1.20	.07	.40	.04	.40
Education										
Secondary/College, ref	-	-	-	-	-	-	-	-	-	-
Undergraduate	.02	.45	.03	.46	.05	1.27	-.00	.43	.00	.43
Postgraduate	.06	.43	.09	.44	.19*	1.22	-.02	.41	.01	.42
5 days + Physical Activity	-.03	.38	-.01	.40	-.10	1.10	.02	.37	.04	.37
High social support	-.06	.38	-.12	.39	-.29***	1.07	.05	.38	.00	.38
Craving target (non-addictive)	.03	.42	-.04	.41	.02	1.20	.02	.40	-.05	.40
Negative Affect	-	-	-	-	-	-	.40***	.03	.42***	.32
Adjusted R^2	**.11**		**.15**		**.32**		**.22**		**.27**	

Note: *p <.05; **p <.01; ***p<.001. ref- denotes the reference category. NA = negative affect

Collinearity tolerance figures and VIF values for the models were > .62 and < 1.55, respectively. Model 1 (Table 2) regressed reports of craving strength in the last week onto nature indicators and control variables. Whilst all nature exposure indicators exhibited the hypothesised inverse associations with craving strength, only access to a garden/allotment and green view from home reached statistical significance. Model estimates of craving strength were on average 1.18 points lower (95% CI = 3.98 to 4.81) when individuals had access to a garden or allotment, than when they did not (4.40 *vs*. 5.58). Examination of the Estimated Marginal Means (EMM) showed that craving strength was lower for those with high greenspace views from home, compared to those with low greenspace views (4.24 *vs*. 5.26).

Model 2 regressed craving frequency onto nature exposure indicators and control variables. Craving frequency was inversely related to garden/allotment access and was 1.32 scale points lower for those who had access to a garden/allotment, compared to those that did not (EEM = 3.49 *vs*. 4.81). Similarly, green view significantly predicted the frequency of cravings, with individuals with high greenspace views reporting less frequent cravings, relative to those with low greenspace views (EEM = 3.35 vs. 4.40).

Model 3 (Table 2) regressed the proposed mediator, negative affect, onto nature exposure indicators and control variables. Consistent with predictions, significant negative associations were observed between negative affect and access to a garden/allotment, high greenspace views and frequent greenspace use. Conversely, no significant associations were observed between negative affect and neighbourhood greenspace.

To examine the hypothesised mediations, a further two regression models simultaneously regressed craving outcomes (strength and frequency) onto nature exposure indicators, alongside control variables and the proposed mediator (negative affect). For craving strength, the relationship between garden/allotment and green view observed within Model 1 were reduced to non-significance in Model 4, following the inclusion of negative affect, suggesting complete mediation of these two variables. Similarly, significant associations between environmental indicators and craving frequency observed in Model 2 were reduced to non-significance, when negative affect was included in Model 5, suggesting again that negative affect mediated the relationship between these variables and craving frequency.

Mediation effects were formally tested using a Structural Equation Model, simultaneously estimating all indirect paths from garden/allotment and green view to craving measures, through negative affect. The specified model initially exhibited a weak fit to the data: $\chi^2(4, N = 149) = 10.79$, $p < .001$; RMSEA =. 11; CFI = .98; TLI = .95; SRMR = .07. Refinements were made to the initial model based on examination of the modification indices, specifically a direct path between garden/allotment and craving frequency was added into the revised model (Figure 2). Alternative models specifying the remaining three direct paths were also tested, but none improved the model fit. The final revised model (Figure 2) showed an acceptable fit to the data: $\chi^2(3, N = 149) = 6.72$, $p > .05$; RMSEA = .09; CFI = .99 ; TLI = .96; SRMR = .06, accounting for 29% and 25% of the variance in craving strength and frequency, respectively.

As shown in Figure 2, both environmental indicators exhibited moderate inverse associations with negative affect, which in turn predicted the strength and frequency of cravings.

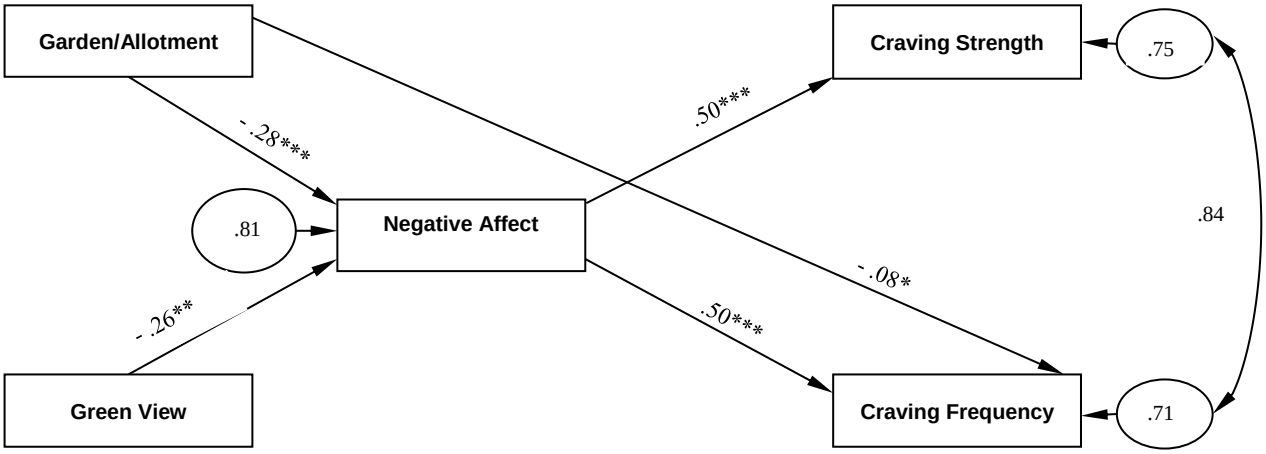

Figure 2: Path diagram of the relationship between nature exposure and craving, as mediated by negative affect. Note: *p <.05; **p <.01; ***p<.001. Statistics depicted along paths are standardised coefficients. Errors terms are reported within circles.

Decomposition of the total effects of the two nature exposure indicators are reported in Table 3. Both environmental indicators exhibited significant indirect effects on craving outcomes through negative affect. This suggests that negative affect mediates the relationship between nature exposure and craving. The significant direct effect observed between access to a garden/allotment and craving frequency indicates partial mediation of this relationship. 63.33% of the total effect of access to a garden/allotment on craving frequency was mediated by negative affect.

Finally, alternative direction models, including the reverse casual pathway, were specified (see Supplementary Materials 3a for further details). Each alternative model specified exhibited a weak fit to the data. Refinements made to the alternative models based on examination of the modification indices, did not sufficiently improve

the models' fit. As shown in Supplementary Materials 3b the original model alone exhibited an acceptable fit to the data.

Table 3: Summary of total, direct and indirect effects of nature exposure and craving

	Green View			Garden/Allotment		
	β	**SE**	**95% CIs**	**β**	**SE**	**95% CIs**
Craving Strength						
Indirect effect	-.13***	.18	-.89, -.22	-.14**	.26	-1.22, -.19
Craving Frequency						
Total effect	-	-	-	-.22 ***	.25	-.84, -.00
Direct effect	-	-	-	-.08*	.21	-1.84, -.46
Indirect effect	-.13**	.18	-.94, -.22	-.14*	.27	-1.27, -20

Note: *p <.05; **p <.01; ***p<.001. SE- bootstrapped standard errors based on 1000 resamples.

4. Discussion

To our knowledge, this study constitutes the first quantitative investigation of the associations between exposure to natural environments, craving for a range of appetitive substances and affect. The aims of the study were threefold: 1) to establish whether increased exposure to natural environments was associated with reduced craving; 2) to assess which types of nature exposure were most relevant to craving, and 3) to examine whether reductions in negative affect underlie the relationships between nature and craving.

In relation to the hypothesised associations between local greenspace exposure and craving, our findings suggest not only that distinct types of greenspace exposure are meaningful predictors of craving, but that these associations are upheld after adjusting for a range of covariates. Notably, having access to a garden or allotment was associated with reductions in both craving strength and frequency.

Residential views incorporating more than 25% greenspace were related to similar reductions in craving. The associations between these types of nature exposure and craving may be practically meaningful, particularly given that our analyses controlled for physical activity undertaken within the same temporal frame that cravings were assessed (i.e. the last week). In other words, our findings suggest that passive exposure to nearby greenspace is associated with reduced craving, irrespective of physical activity level.

That neighbourhood greenspace did not significantly predict craving or affect within the multivariate analyses is somewhat surprising, considering the bivariate associations observed here and the affective benefits of high proportions of residential greenspace noted elsewhere (Astell-Burt, Mitchell & Hartig, 2014; Beyer et al. 2014; Cohen-Cline, Turkheimer & Duncan, 2015; May et al., 2010 5; Van Herzele & de Vries, 2012). With few studies examining the relative influence of multiple aspects of residential greenspace exposure, our findings may reflect shared variance between greenspace indicators. A potential explanation is that gardens/allotments and green views operate as micro-restorative settings, which, through immediate visual access, afford more effective restorative opportunities (Hartig et al., 2014; Kaplan, 1995) compared to distal greenspace measured at the neighbourhood-level. Certainly, the affective benefits of greenspace close to the home have been demonstrated elsewhere (Cox et al., 2017; Ward-Thompson et al., 2016; Kaplan, 2001; De Vries et al., 2013; Shin, 2007), and the greater relative influence of private greenspace over neighbourhood greenspace has been observed in relation to general health (Dennis & James, 2017). Moreover, given the recurrent nature of craving (Hofmann, Baumeister, Förster & Vohs, 2012; Skorka-Brown et al., 2015) greenspace characteristics that are visible throughout the day may

conceivably be the most beneficial for attenuating craving. Nonetheless, considering the inverse associations and bivariate effects observed, the potential benefits of residential greenspace exposure to affect and craving should not be discounted. Given the relatively small sample, the null findings may reflect a lack of statistical power to detect smaller, but still meaningful associations.

Contrary to observations in individuals undergoing drug and alcohol rehabilitation (Bennett et al., 1998; White et al., 2016) visits to public greenspace were not associated with reduced craving. These inconsistent findings may be due to methodological differences between studies and samples. Specifically, the aforementioned studies examined prolonged nature exposure (between three hours and several days) with immediate follow-up assessments, in contrast to retrospective reports of annual visit frequency and craving experienced over the last week measured here. As the pattern of associations between nature exposure and well-being varies according to how recent the visit was (White et al., 2017), studies mapping real-time measurements of craving to individuals' immediate environments using Global Positioning Systems (GPS) may yield a further understanding of the most relevant aspects of nature exposure (e.g. Doherty, Lemieux & Canally, 2014). Moreover, the level of craving in the current sample is likely to be less intense than in the rehabilitation samples.

Consistent with the hypothesis that affect regulation may be one mechanism that underlies the relationships between nature exposure and craving, path analyses suggested that distinct types of nature exposure have both direct and indirect influences on craving. Specifically, the inverse associations between proximal greenspace exposure (green views, assess to a garden/allotment) and craving strength were fully mediated by reductions in negative affect. High greenspace views

from home were also associated with lower negative affect, which in turn was associated with less frequent craving. Conversely, associations between craving frequency and access to gardens/allotments were only partially mediated by negative affect. Taken together, our findings suggest that inverse associations between nature exposure and negative affect noted elsewhere, may also extend to lower frequency and intensity of cravings Although, our cross-sectional data is unable to establish cause and effect, alternative path models were tested and exhibited a poor fit to the data, supporting the original conceptual model.

Partial mediation of the relationship between craving frequency and access to gardens/allotments indicates that additional mechanisms may contribute to this association. One possibility is that the association results from a complex interplay of cognitive and affective mechanisms. Given that nature exposure is associated with improvements to a number cognitive domains (e.g. *impulsivity*, Kuo, Taylor & Sullivan, 2002; *rumination*, Bratman, Daily, Levy & Gross, 2015 and *self-control,* Kuo, & Faber-Taylor, 2004), which independently predict craving and abstinence (Doran, Spring & McChargue, 2007; Casselli et al., 2013; Nigg et al., 2006), future research could explore these potential mediating pathways.

4.2 Limitations

Whilst providing unique insights into the relationships between nature exposure, affect and craving, the present study is not without its limitations. First, the cross-sectional approach limits our ability to make causal inferences. Despite substantial experimental evidence demonstrating affective improvement following exposure to natural environments (McMahan & Estes, 2015) it cannot be ruled out that individuals who already experience lower negative affect and craving move into

more natural settings. Alternatively, it is possible that other third factors (e.g. personality) not accounted for within the current study may covary with craving, affect and nearby greenspace exposure. Second, the majority of the data presented here is based upon retrospective self-reports (i.e. last week for outcome measures and last twelve months for frequency of use indicators) which may introduce recall bias. We also recognise that use of LSOA data (circa 2001) introduces potential error caused by variations in neighbourhood greenspace coverage over time. Third, measurement of socio-demographic status within the study was limited to education and area-level deprivation. Given that use of addictive substances and greenspace access are influenced by marked social gradients (e.g. see Sections 2.2.1 and 2.2.1 for details) it is possible that the associations between nature exposure and craving, or craving target and craving, may be moderated by socio-demographics. Although additional analyses testing these interactions did not find any significant moderation effects in the current dataset (contact authors for further details), we cannot rule out this possibility from socio-economic measures not captured here (e.g. social grade, income). Fourth, whilst craving is reported to contribute to the maintenance of a variety of health-damaging behaviours (Cosci et al., 2016; Richard et al., 2017; Sayette et al., 2016), abstinence rates were not obtained, thus it is unclear whether the attenuated craving extends to reductions in health-risk behaviours. Finally, the small and homogeneous sample limits both statistical power and generalisability. Further studies utilising: 1) experimental manipulations of nature exposure on concurrent measures of craving, and 2) larger-scale cross-sectional approaches accounting for a broader range of socio-demographics and abstinence rates are therefore needed to assess the robustness and behavioural consequences of our craving findings.

4.3 Concluding comments

Craving contributes to the maintenance of a variety of health-damaging behaviours such as smoking, excessive drinking and unhealthy eating. The current study provides novel evidence that greater local contact with the natural environment, in the form of green views from the home and access to gardens/allotments, is associated with lower frequency and intensity of cravings for a range of substances. Moreover, our findings suggest that negative affect may play an important part in mediating this relationship. Consistent with previous studies, we found that: a) greater nature contact was associated with lower negative affect; and b) lower negative affect was associated with reduced cravings. If further evidence can corroborate that these relationships are casual, then proximal greenspace may offer a cost-effective and unobtrusive means of reducing both the intensity and frequency of cravings. Recognition of the associations between nearby greenspace exposure, affect and craving advocates the need to protect and invest in such resources, in order to maximise the public health benefits that they may afford. Furthermore, if our findings are substantiated by experimental work, then nature-based interventions may assist individuals attempting to withstand problematic cravings, enabling them to better manage cessation attempts.

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Acknowledgements:

This study was conducted as part of the first author's MSc in Psychological Research Methods and supervised by the second author.